Chemical Process Control
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Lecture - 46
Introduction to Batch Process Control

Hello students. Welcome to the final section of this course, wherein we will try to discuss control topics related to batch processes. So far whatever we have seen mostly we considered that processes are continuous, even though I did not mention it specifically. Most of the times, we are looking at things, which are steady in terms of time or the objective is to make, keep the things steady with respect to time.

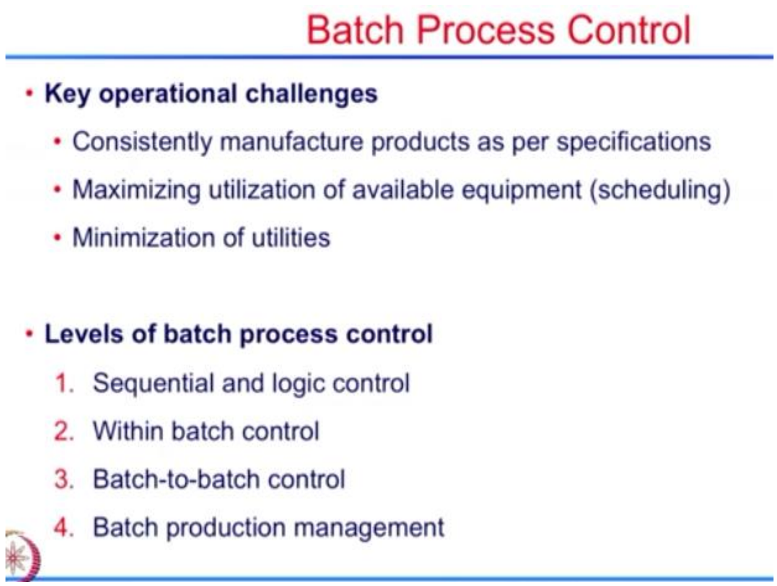
In this particular section, we will see how things differ when it comes to batch processes. In fact, batch process control is a little trickier compared to continuous process and we will see how that is done. In terms of the objective in this week, in this section what we are going to do is, first we will try to differentiate how batch control is different from continuous processes.

Learning Objectives

At the end of this lecture, you will be able to

- Differentiate batch control from continuous process control
- Classify batch control tasks into various levels
- Draw ladder/logic diagram to convert a recipe into sequential logic

Later on, we will see when it comes to batch, there are different types of the control task, which have to be incorporated and we will also see how those connect with continuous processes. Lastly, we will see how these things are implemented in a real controller and we will also see that some of these portions would also carry forward to continuous processes. So let us get started.



When it comes to batch, the main thing that distinguishes a batch process from a continuous process is that the batch process is inherently dynamic. Things keep on changing as a function of time, things are not continuous per se, what I mean by that is you always have a start and stop type of behavior in a batch process. Because of that, you make things in discrete quantity or discrete quantities, and every batch can in principle, mathematically be different from each other.

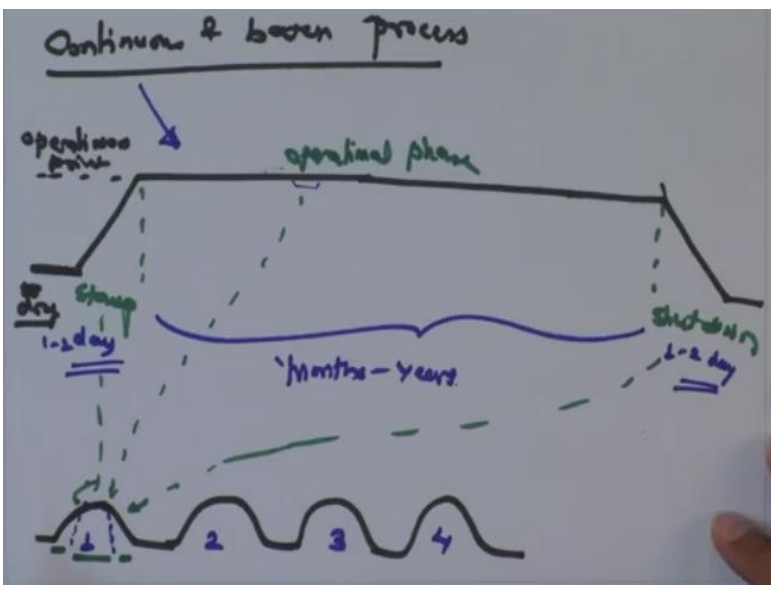
However, the operational objective is that every batch has to look exactly the same as the previous one, that is when you have a consistent product. Unless you have some sort of automation into your process, you cannot ensure that every batch which you are producing at the different time of the day comes out to be and operated by different operators comes out to be exactly the same. That is one of the major objectives of a batch process that you want to ensure that every batch has a consistent productivity and product specifications.

The second one is, as you are making different products typically when you have a batch process, the reasons the way you can incorporate, 1 of the reasons why you have a batch process is that you have sort of seasonal production or you make multiple products using similar type of process synthesis route, so you will lot of times end up sharing the same sort of same reactors or separation equipment.

Typically in a batch process, you are given some target on a monthly basis and you have to ensure that within that month, you have to plan your batches, such that you get the same the desired amount of different products, A, B, C or whatever you are producing using the set amount of equipment and that is typically known, that sort of problem is known as the scheduling problem. Typically it is a sort of a higher level problem compared to a controlled problem per se, but a lot of times, there is an interaction between scheduling and control.

Lastly, you also want to do all these while consuming a minimum amount of resources, so there is sort of an optimization also built in. So when I say that when we see last week, we had seen the advanced controllers are used to optimize a certain economic performance, some similar optimization based controllers would also be present for a batch process as well.

In terms of how batch processes differ from a continuous process, the main difference between the batch process and the continuous process is that there is a sequence start up and shut down in a batch process. Let us say if I want to compare a batch and a continuous process.



In a continuous process, let us say refinery or any petrochemical operation, what you do is, you typically have a startup of that particular process. So when things are let us say warm, or you can say dry, start, there is nothing operational, that is like a shut down state and then you bring all the things to the operational level and then you try to maintain the operation at that level for as much amount of time till you have a planned shutdown. So this will, so this is start up and this is the shutdown.

Now here I am saying that things remain steady throughout this entire course, what I want to say is your objective is to maintain things at that operational point. Sometimes there will be minor variations around this point depending on what advance controller is telling you, but more or less what you will try to do is, you will want to, you can easily distinguish there are 2 different points.

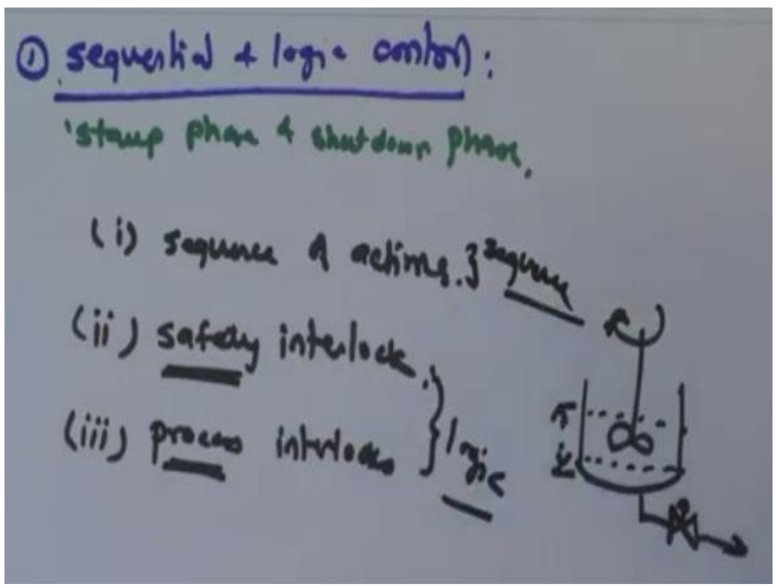
One is a dry point, where nothing is operational and there is an operational point where you are going to get a product and this difference between the 2. Let us say if start-up takes about a day or 2 or similarly shut down will take a day or 2, and in between the process may operate for months to years till you take a shutdown. So you can see that the start-up and shut down are very rare phenomena in a continuous process. So this is for a continuous process.

Most of the times, the operator sees a steady plant and the objective is to maintain the production or the plant around this nominal point. And that is why all the control studies, which we have done so far in this course, the objective was always to have a set point and try to maintain that set point in the presence of disturbances and some small setpoint changes, which are governed because of some advanced controller, which are dictated by some advanced controller.

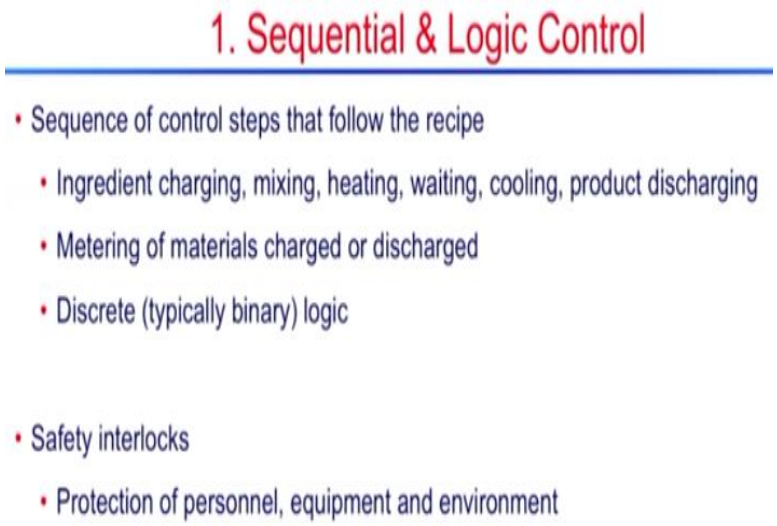
When it comes to a batch process, however, what you have is, you have a dry point and then you have a start-up, operation, again shut down. You come back and you can see that every time, every cycle or every batch, so let us say this is batch 1, batch 2, so every batch has a start-up, small start-up time, small shut down time and small operation time. This is a start-up, this is shut down and this is an operational phase.

You can see the magnitude in terms of the relative time of these three phases, they are relatively of the same order when it comes to a batch process. Now I am talking about a very general batch process. There might be some batch processes, where the operational phase goes for about a day or 48 hours or so, but still, more or less, it is still within some hours, and not as big as months or years. So you can see that the batch process always things keep on changing as a function of time and that makes control problem little tricky.

What we will do now is, in terms of how we end up controlling such kind of a batch process or how do we rather than control, let me talk more about the operation, because control becomes part of the operation. How a batch process is operated and what sort of control systems, what role control systems play into it. So essentially there is four key tasks which any operational or controller system has to perform in a batch process. And I will also try to connect how these parts relate to a continuous process as well.
The first part is known as sequential analogic control.



As the name suggests, it deals with sequence and logic. This deals with the start-up phase as well as the shutdown phase. The activities of which you have to conduct in a start-up phase and a shutdown phase, those would come inside the sequential analogic control.



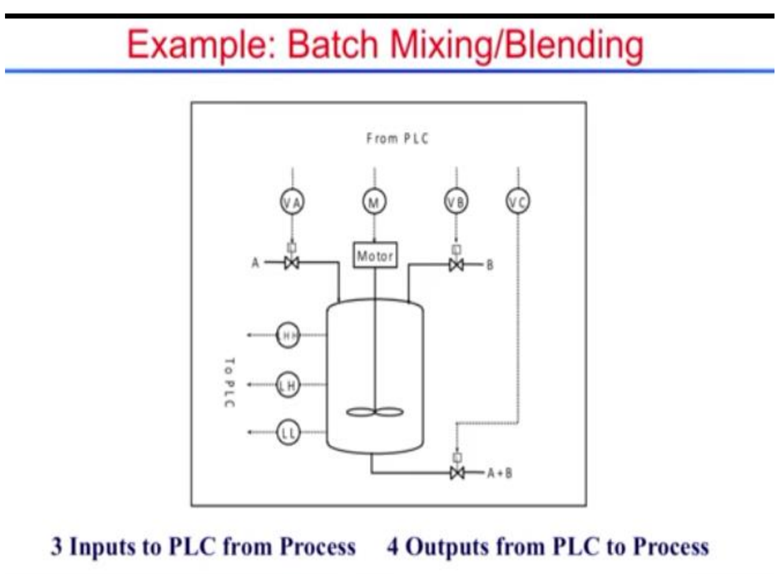
Same way if you want to connect with the continuous process, the start-up of a continuous process, as well as plant shutdown of a continuous process, would also involve such kind of sequential analogic control.

The only disclaimer here is that this kind of controlled logic will be activated only during those start-up and shut down times, but most of the time, these systems would sort of remain idle. Because the plant operates at its an operational point in a continuous plant. However in the batch process, these sequential analogic control gets activated during every batch and what it does is, it allows you or it ensures whatever is the task, which has to be performed in a batch, which typically is maintained within what is known as a recipe. Every batch has a recipe, which says that mix A and B and then heat the reaction mixture. Wait for some time for the reaction to take place and then start removing the product, so all those things.

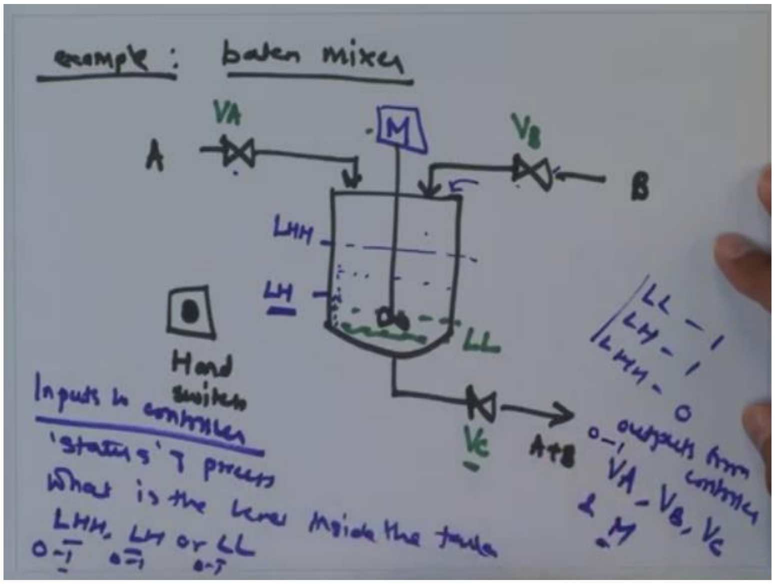
In a batch process, generally it is based on these different steps and these steps have to be carried out in a particular sequence, so ensuring that particular sequence in an automated fashion, would be the job of a sequential control part and there is also sometimes, there is logic associated with it that you want to make sure that when you are adding something, some other things have to be specified. Some specs have to be maintained before the product is removed. There is also some sort of logic associated with some of these steps. All these sequences, as well as logic for a batch recipe, would be incorporated using a sequential and logic control. Mostly this is a binary logic. Along with that, all it deals with are three types of things, one is a sequence of actions, what we saw. The other thing it has to ensure is safety interlock. Safety interlock means, you have to ensure that the steps, which you are going to take, they ensure the safety of the particular process, people who are around it as well as the safety of the environment and there are generally safety constraints associated with it. Unless those safety conditions are satisfied, you will not move on from 1 step to the another. All these sequences, the logic around that sequence will also be dictated by the safety conditions.

Sometimes there are also conditions related to the process. There will also be some process interlocks. An example of that would be, you would not start mixing unless there is a certain level inside a particular vessel. So you do not want to move. Let us say if you have a vessel and you want to start the impeller, you will not start it unless there is a certain minimum level. This is not really a safety related interlock but is more of a process sort of an interlock. Where you want to say that the task of starting the impeller should be done, only when there is sufficient amount of level inside that particular vessel. Similarly, if you want to withdraw the product, a similar thing would be there, you will start withdrawing the product, withdraw the product unless the level is above a certain value or so. So all these things, this mostly falls under logic part and this is more of a sequence.

All these sorts of actions would be considered or would be part of this logic, which is known as sequential and logic control.



Let us now take a very simple example of mixing or batch blending to explain to you how this sequential and logic works and how it can be implemented.



We will take the example of a batch mixer. This is a mixer which is going to mix 2 streams, 1 is A and another one is B. It also is provided with an agitator and there is a way to remove the product, which we will call as A+B. Now let me explain to you how this process looks like.

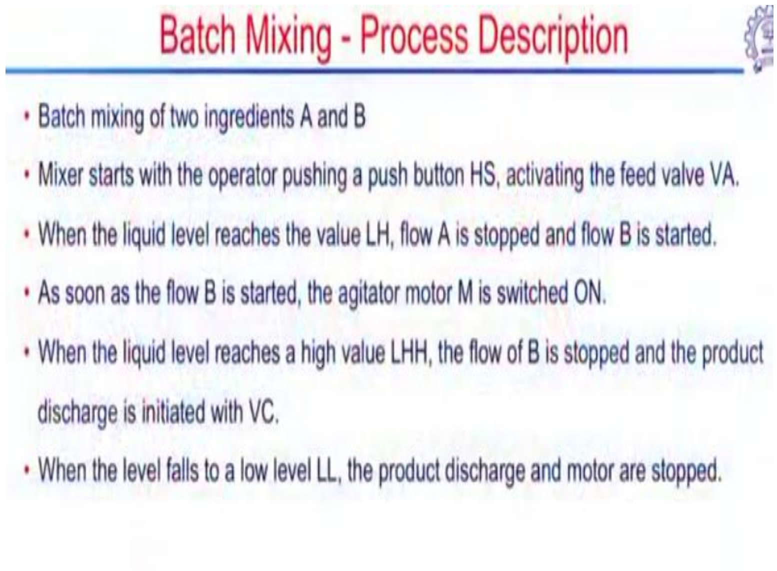
In this process, what it says is, first the operator in order to, let us consider this is the only process, which you want to operate. So the operator has to start the switch. This is known as the hand switch. So the operator will press the button. When the operator presses the button, this particular valve V_A will open and it will start putting material into this particular vessel and addition will be done till a certain amount of level is reached inside this vessel. Let us call it as L_H. So till the level reaches L_H, you will have the addition of A. Once the entire amount of A is added, the level is L_H at that time, you will stop this valve or close this valve.

The second ingredient, which is B will start entering the vessel. Again the level will increase and now you are adding B into a pool of A and you want to mix it. So the agitator will also be switched on. If this is a motor, then this motor will also be switched on when the level is above

L_H and addition will take place till your level reaches a certain point known as L_{HH}. So when the level reaches L_{HH}, you have added the required amount of B as well as A together.

Everything is mixed, and now you would start with. Now we will start withdrawing the product. This third valve, let me even name all of these valves. So this is known as V_A valve, this is V_B valve, this is the motor and this is the V_C valve. When the level reaches L_{HH}, you will close the V_B valve, you will open the V_C valve so that the product can be removed and while removing the product, you want to ensure that still the A and B mixing is there. The motor will keep on running even during that time and the product will be withdrawn till the level reaches a minimum value of L_L. When the level reaches L_L, that means you have removed the entire product. The valve V_C will close as well as the agitator will also stop. For correctness, let me show that this level is like this so that the agitator is always below the minimum level. So that is the process. Let us see how.

You can notice that this process has a lot of steps. It has some logic as well in terms of up to what point you should be adding a particular ingredient and then what time, what are the 2 things which should be together. For example, the addition of B as well as motor, what things should not be together, like V_A and V_B should not be open at the same time. All these things are there. How do you ensure this automatically? How the controller will make sure all the things operate in the correct sequence? That will be the part of sequential analogic control. For that, what the process needs is some inputs from the system.

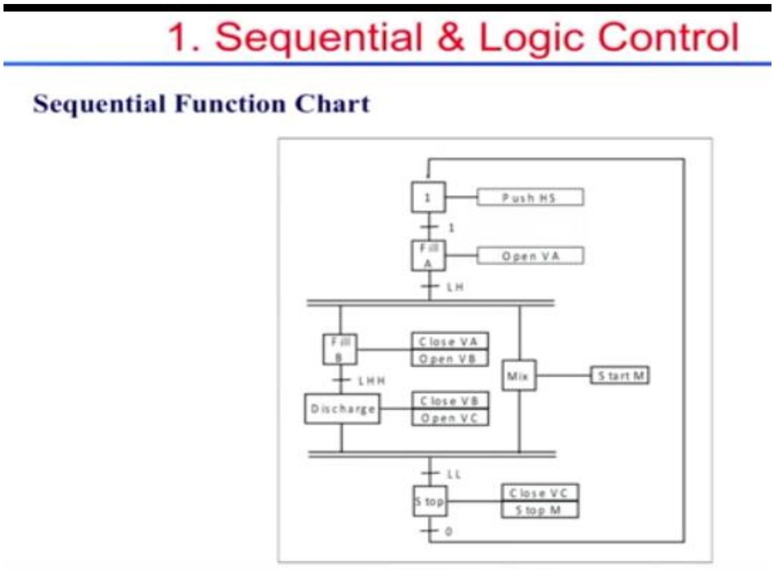


For this system, there are three things the controller needs to know in order to decide what should be done. The inputs to the controller are the status of the process. So which things would give me the status, what is the level inside the tank. That is L_{HH} whether it is L_H or L_L. Typically every one of these would be associated with the binary signal of 0 and 1. So what it will tell me is if L_{HH} is 0, that means the level is below L_{HH}.

When L_{HH}=1, which means the level has reached L_{HH}. Similarly, for L_L or L_H. Those are the 3 things which will tell me where my level is lying. Let us say if L_L is 1, L_H is 1 and L_{HH} is 0 that means I am above L_L, above L_H and below L_{HH}, so I am somewhere here. That way using these 3 tags, your controller will know where exactly your process is and there are 4 things, which the controller will control.

Outputs from control will be the things, which you can manipulate in this process, which is valve V_A, V_B, V_C and this mixer M, this motor M. So that the valve can be opened or closed and the motor can be switched on or off and for simplicity, we will consider that these valves are on and off type of valves. When I say V_A is 0, which means a valve is closed, when V_A is 1, the valve is open. It is not necessary that it should be the case. You can also have a valve, which opens by a certain percentage, but for simplicity, let me just consider that all these valves are also binary and the motor is also binary in a way that whether it is on or off.

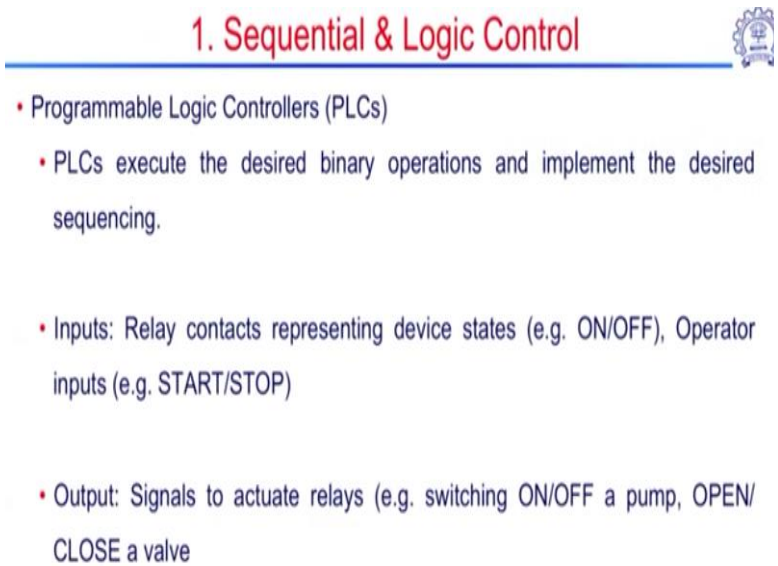
The first thing in order to incorporate this is you need to ensure that you need to formulate what is known as the sequential and logic diagram or sequential functional chart, which tells you what are the sort of actions, which are going to happen sequentially. What actions are going to happen parallelly, what are the different steps inside the process?



Let us see how such a kind of diagram can be drawn for this system. Here is a sequential function chart for this particular system and you can see that it starts with this point, where there is a push button, which the operator is going to push. When the operator pushes this hand switch HS, 1 is the value which goes to the controller and when the value is 1, it will open the valve V_A. So when it opens the valve V_A, it will start filling the material A into the tank. The level inside the tank will keep on increasing and when the level reaches the value of L_H, at that time, 2 things are going to happen. That is why it is shown as parallel tracks after this. 1 is you will start filling B, for that you have to close valve A and you have to open valve B and parallelly you have to start the agitator. The motor will also start. So these 2 things will go on parallel.

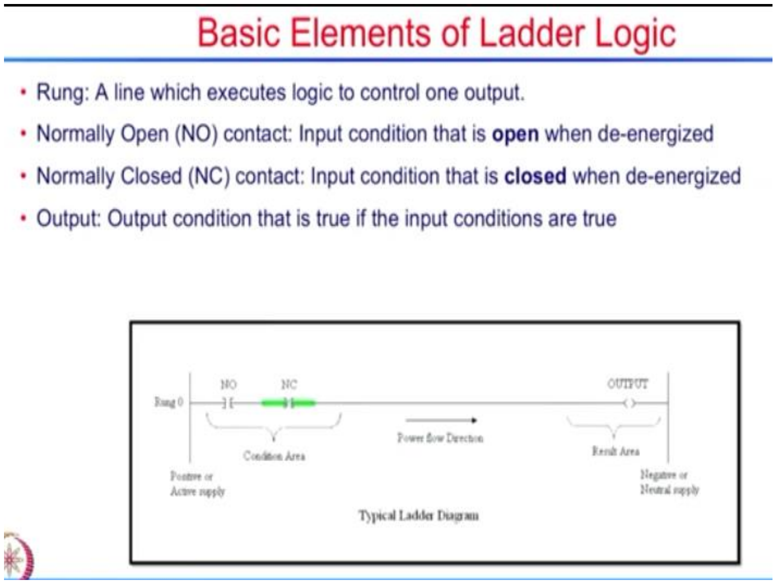
Within this left side arch, when the level reaches L_{HH}, at that time, you will start the discharge, so you will have to close the valve V_B and open the valve V_C while there is no condition in terms of, there is no change of status for the mixer, when the level is L_{HH}. Because you have to keep on mixing even though the product is discharged and you will again converge these 2 lines when the level reaches L_L.

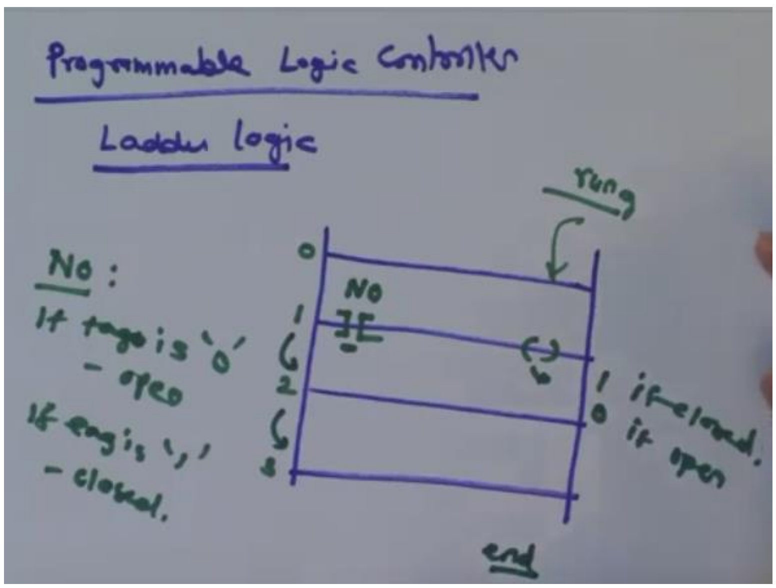
When the level reaches L_L, at that time, you have to stop the operation. That means you will close the product valve V_C, will stop the motor and the signal which will go back is 0, that means the process is stopped and it will go back unless you push unless the operator pushes this button, 1 will not go forward and the process will not start again. That is how you can draw a sequential functional chart for such kind of a system.



In order to incorporate this in a real controller or hardware, we use programmable logic controllers, also commonly known as PLCs. So this PLCs would execute the desired binary operations, all these sequences based on the signals, which come from the process like here you are getting these inputs about the level inside the tank and accordingly it will give signals to these different valves and which will be executed in a process.

Here I am saying that these are mostly binary logic, but it is not necessary. Nowadays, these PLCs can also execute non-binary operations in terms of a control law calculation, PID controllers can also be implemented inside PLCs. Let us now see if you really want to incorporate this into programmable logic control, how do you go about it? The logic which this PLC controller uses is known as the ladder logic.





It uses the ladder logic and it is essentially a ladder. All of you know what is a ladder and ladder has different rungs. Every step in a ladder is known as a rung and each rung will have a certain logic or step associated with it. If you say these rungs are numbered as 1, 2, 3, 4, then every 1 of those lines will have a certain set of code, which is associated with it and there will be output at the end of it.

The output will be at the end of this line and there will be some conditions with respect to the different variables of that particular system. There are 2 basic types of logic actions, which are done there. 1 is something which is known as normally open contact, which means unless this particular variable becomes 1, this line will not get connected. This line will remain open for a binary or variable value of 0. So when you have a normally open contact, so if a tag is 0, it is open.

If the tag is 1, then it is closed and the idea is if this particular thing is closed, then this output will become 1. If the entire thing is closed and if there is some discontinuity and everything inside this line is not closed, then the output will be 0. So that way, any piece of action will be executed along a run and then every instance of the controller, it will go from 1 rung to the another, till it reaches the end.

There may be some 1000, 2000 lines of rungs inside a programmable logic controller. During every execution of a PLC, it will go through all these steps and then come back and just for your information, typically the cycle time is about some milliseconds. You can see that these actions take place very fast. Execution of these different rungs takes very fast and typically the cycle frequency of this PLC controllers is of the order of milliseconds. And mind you these rungs are generally 1000s of rungs are there within a single PLC.

Let us try to see how these PLC can be used to incorporate the sequential and logic control for this particular batch blender. We will take a short break and when we come back, I will actually show you on simulator how this can be done. It is a freely available simulator. I will show you how you can access it and we will see how this can be implemented for this simple example. We will take a short break here. Thank you.